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J. Abedi and S. Banerjee

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Jalal Abedi, Sujit Banerjee
Institute of Paper Science and Technology
500 10th Street NW
Atlanta, GA 30318

Abstract

Infrared thermography was used to determine surface temperature maps of veneer and wood flakes during drying. These maps are proportional to the surface moisture distribution. The coefficient of variation (COV) of the surface temperature reflects the properties of the wet line. As the wood dries, the COV increases gradually, and then surges when the surface water film is broken, and the wet line moves into the wood structure. The shape of the relationship between COV and moisture content depends upon factors such as the type of furnish, wood species, and drying temperature.

Keywords: infrared, thermography, drying, variation, wet line, surface.

Introduction

Drying wood evenly is important for the development of good product properties and for preventing press blows and other process problems. Infrared (IR) thermography has been used for knot detection (Murata and Sadoy 1994; Quin *et al.* 1998), and, more recently for determining energy absorption (Antti and Perre 1999). The surface temperature of wood is influenced by the surface moisture, since evaporative cooling occurs to a greater extent from the wetter regions, which are, then, proportionately cooler. Hence, IR thermograms should illustrate the changing distribution of surface moisture during wood drying, and provide insight into the mechanism of moisture removal.

Experimental

Thermograms were taken with an AGEMA 900SW/TE system, composed of an IR scanner equipped with a 40-degree FOV IR lens and a high-speed system controller. The scanner detects radiation in the 2-5.4 μ range, where temperature is the only variable. The system is able to analyze images at the pixel level of resolution, and compensates for transmission through the atmosphere (Incropera 1990; Thermovision 1993). An emissivity value of 0.92 was estimated by heating a sample of veneer and measuring its temperature with both a thermocouple and the IR scanner. It was then adjusted until the IR-derived temperature corresponded to that obtained from the thermocouple.

Veneer was obtained from the Georgia-Pacific veneer mill at Madison, GA. Samples were cut from different isothermal regions of the sheets, and their moisture content determined. Pine flakes were collected from the Georgia-Pacific Dudley, NC, facility, and aspen was acquired from the Potlatch Grand Rapids mill. In initial laboratory work, veneer was cut into 12.7 x 8.9 x 0.42 cm pieces, and oven dried at different temperatures. The sample was dried in an oven with the door open, and the focal plane of the scanner was positioned approximately 50 cm from the wood surface. Thermograms were taken once every minute, after which the sample was quickly weighed and then replaced in the oven.

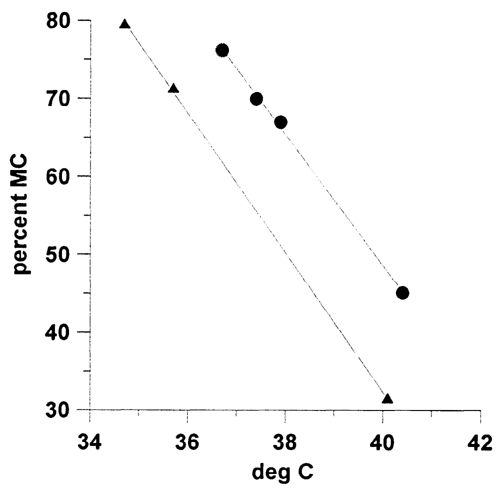

Figure 1: Plot of surface temperature vs. MC for pine veneer.

In order to determine the relationship between temperature and moisture, two green pine veneer sheets were removed from the conveyor at Madison just after the peeler, and IR thermograms taken immediately. Samples were cut from zones corresponding to different temperatures, and their moisture content determined.

Results and Discussion

The relationship between MC and temperature for the two green veneer sheets are linear as shown in Figure 1. The lines are almost parallel and are offset by about 1.7°C. This offset reflects a difference in the initial sheet temperature. The average temperature difference between the two sheets was 0.7°C. However, when knots (which were at higher temperature) were excluded, the difference increased to 1.4°C, which compares well to the 1.7°C offset in Figure 1. The slopes of the lines are similar, indicating that the rate of evaporation is proportional to the moisture content within the range considered. This linearity should hold as long as free water is being lost; curvature is expected below the fiber saturation point. Importantly, the MC is that of the wood throughout its thickness, whereas the thermogram is a surface measurement. The surface moisture must, therefore, be proportional to the overall moisture content. These results demonstrate that surface temperature is an indirect measure of moisture content.

Thermograms were taken of veneer pieces as they dried in the oven. Plots of the coefficient of variance (COV) of the surface temperature *vs.* MC are shown in Figure 2 for yellow poplar and pine. The MC is normalized to allow comparisons across sheets. Since the surface temperature is a measure of the MC, the COV must reflect the variability in MC. The traces for hardwood and softwood in Figure 2 are remarkably similar, except that the COV is slightly higher for pine than for yellow poplar probably because the softwood matrix is less homogenous. In both cases, the COV rises as the wood dries to an MC of about 20%. It is very likely that the wet line resides at the surface during this period, and the surface water film thins during drying. Differences in the heat transfer to the wood surface are emphasized as the film thins and the COV increases. The sharp increase in COV at an MC of about 20% almost certainly reflects breakage of the surface film and the onset of bound water evaporation. The COV rise occurs

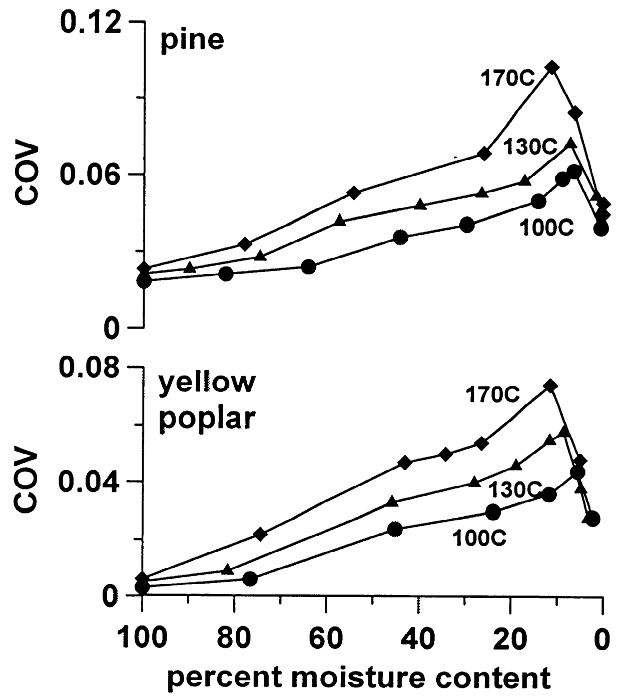

Figure 2: Dependence of the coefficient of variation (COV) of the surface temperature on moisture content for veneer.

earlier at the higher temperature, reflecting earlier breakage of the film. It then decreases to a common value when the wood is dry and reaches a more uniform temperature. Analogous data for drying individual pine flakes are illustrated in Figure 3. Since flakes have a higher surface area:volume ratio as compared to veneer, proportionately more moisture resides on the surface, and the COV remains relatively stable during early drying. The position of the COV maximum occurs later for the flakes, since the surface water film breaks at lower overall moisture content.

In conclusion, IR thermography offers a method of visualizing the wet line as wood dries. Wet line control provides considerable environmental benefit during high-temperature drying (Banerjee et al. 1998). As wood dries, it is evaporatively cooled by the departing moisture, and the tissue temperature remains either at or below the boiling point. As the surface dries out, i.e., as the wet line begins to ingress into the matrix of the wood, the surface temperature rises, and terpenes and wood breakdown products are released (Su et al. 1999; Barry and Corneau 1999). Hence, maintaining the wet line at the surface for as long as possible allows the wood to be evenly cooled by the evaporating water and minimizes VOC release.

Acknowledgement

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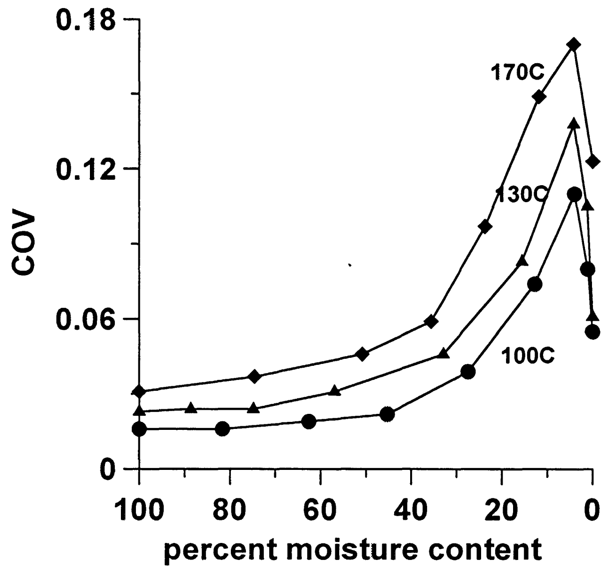

Figure 3: Dependence of the coefficient of variation (COV) of the surface temperature on moisture content for pine flakes.

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